Medical Oxygen Sensors

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The Gas Laws

Boyle's Law.

For gases; such as Air, Oxygen, Nitrogen & Helium, under ordinary conditions of pressure and temperature.

"The absolute pressure is inversely proportional to the volume provided that the temperature is constant."

This can also be expressed mathematically as :-

$P \times V = K$

Pressure x Volume = Constant

If P_1 V_1 are the starting conditions and P_2 V_2 are the end conditions

$P_1 \times V_1 = P_2 \times V_2$

Temperature is assumed to be constant.

Dalton's Law.

More correctly this is Dalton's 1st Law.

If a closed vessel contains a mixture of two different gases which have no chemical action on each other then

"The total pressure is the sum of the pressures which the quantity present of each gas would exert if it alone occupied the vessel".

When the gas is air

$Pt = PO_2 + PN_2$

where Pt is the total pressure

PO_2 is the partial pressure of Oxygen and

PN_2 is the partial pressure of Nitrogen.

At the Standard pressure of 1 Bar in air

1 bar = 0.21 bar + 0.79 bar

Henry's Law.

Liquids are similar to gases but have more closely packed molecules.

Molecules of gas can move into liquids . Water contains dissolved Oxygen which allows fish to breathe by using their gills to separate the oxygen molecules from the water.

"The amount of gas which dissolves in the liquid is directly proportional to the partial pressure of the gas adjoining it".

By increasing the pressure of the gas on the surface of a liquid we increase the partial pressure and allow more molecules to dissolve into the liquid.

In addition to pressure, different gases have different solubility coefficients. i e. Different gases will dissolve different quantities of their molecules into different liquids at STP.

Temperature also affects the ability of a liquid to dissolve the gas.

When 100% Oxygen is suddenly introduced into contact with a liquid e.g. the Oxygen level is raised from 20.9% to 100% the Oxygen will begin to pass into the liquid. The liquid takes time to reach a new equilibrium . It starts quickly to take up the Oxygen but then becomes slower and slower as the liquid reaches saturation.i.e. The partial Pressure of the gas is initially much higher than the partial pressure of the dissolved gas and gas passes into the liquid. As the difference in the partial pressures become smaller the transfer from gas into liquid slows down.

If the gas is then suddenly removed e.g. 100% Oxygen to Air 20.9% then the liquid contains more gas than the surrounding atmosphere and molecules transfer out of the liquid back into the air. The same time delay applies.

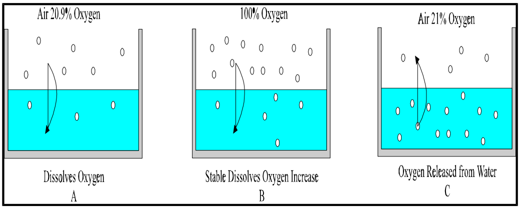
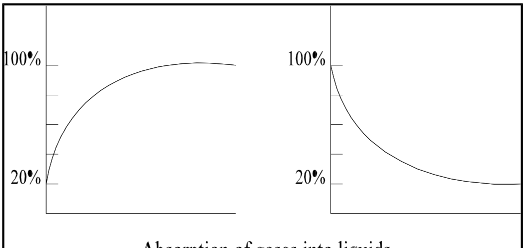


Fig. 6 The absorption of gases into liquids.



Absorption of gases into liquids

Each of these gas laws plays a vital part in the mechanism of electrochemical galvanic fuel cells and the measurement of Oxygen.The volume of the sensor is fixed so any increase in pressure directly increases the partial pressure of Oxygen in any gas mixture inside the sensor.

Increasing the partial pressure of Oxygen, increases the number of molecules available for reaction at the sensing electrode producing a higher output.

As the Temperature of the gas is increased so the speed the gas molecule move increases and therefore ensures more molecules come into contact with the surface of the liquid. Temperature of the sensor body increases the solubility of the electrolyte making it easier for the Oxygen molecules to pass into the electrolyte. More Oxygen dissolved into the electrolyte, the larger the sensor output.

At STP the partial pressure of O_2 is .209

At STP the percentage O_2 present in air is 20.9%

20.9% is the most accurate setting for the % of Oxygen in air at sea level.

Therefore the Calibration of the Analyser should always be a setting of 20.9% at sea level assuming 1 bar atmospheric pressure and a temperature of 25°C (STP.)

It is important to ensure all Oxygen measurements are made at 1 Bar. Any container e.g. plastic bags or Tee pieces must allow the gas to vent freely into the atmosphere. Only when the unrestricted gas has reached equilibrium with the surrounding atmosphere of 1 Bar will the measurement be accurate. Occluded Tee pieces and plastic bags will produce inaccurate measurements.

If it is necessary to measure a flowing gas, the analyser should be calibrated in gases with the same flow rate.

e.g. If a flow rate of 5 litres/min is normal , then the calibration gases(Air 20.9% and Oxygen 100%) should be at 5 litres/min.

Flowing gas is turbulent and therefore more efficient in presenting the measured gas to the sensor. However restricted flowing gas can cause backpressure and inaccuracies.

Flow rates as low as 100cc/min to 500cc/min are all that is required by the sensor to achieve good readings.

Gavanic Fuel cell Oxygen Analysers

Initially, fuel cells were designed to produce electricity in space, using Oxygen as a fuel and are used by NASA in the space program to power manned space vehicles. They were subsequently miniaturised into the present form, providing normally 1 to 200 microwatts of power and became known as micro fuel cells. Micro fuel cells consume oxygen in the production of current.

This sensor is packaged as a complete self-contained and expendable transducer. When the chemicals are exhausted the sensor is discarded and replaced. These sensors require no external applied potential (battery) to work. They consume Oxygen and produce a small electrical current. Some types produce sufficient current to drive an analogue meter, direct, without any electronics or batteries.

Analysers employing this type of sensor have been available since the 1960's

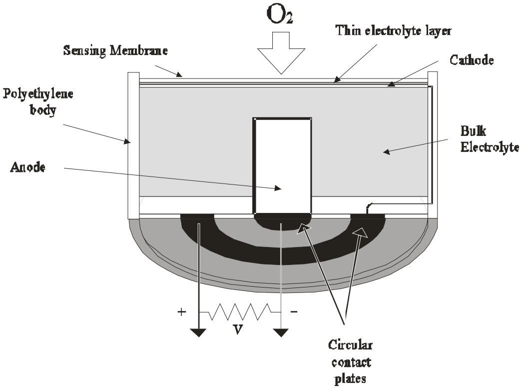
The simplest Oxygen analyser therefore employs no electronics but is simply a sensor and a 100 micro Amps moving coil meter. The galvanic sensor will be discussed in depth later.T

The choice of method used to measure oxygen depends on the location, the accuracy required and the level of portability and robustness needed.

The Galvanic Oxygen sensor

The sensor is packaged as a complete self contained and expendable transducer so that when the chemicals are exhausted the sensor is discarded and replaced.

The basic constituents of a sensor are a lead anode and a gold plated cathode with a solution of Potassium Hydroxide as an electrolyte.



The cathode is a convex metal disk plated with a noble metal e.g. gold, silver, platinum Rhodium.etc. with numerous perforations. It is designed to facilitate the continuous wetting of the upper surface and therefore contains a small amount of electrolyte between the membrane and the cathode.

This electrolyte layer is to ensure that the cathode is always wet . The holes ensure minimum internal resistance during the oxygen sensing reaction. When Oxygen is diffused into the sensor through the membrane the lead is oxidised into lead oxide and the reaction produces a small current between anode and cathode externally.

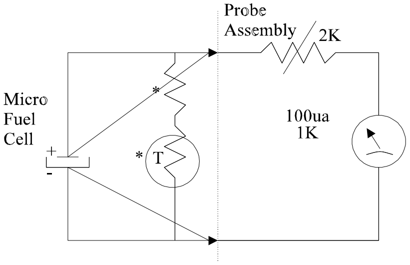
The lead anode is specially designed to maximise the amount of metal available for the reaction .For this reason it is not solid but small particles bonded together. This increases the surface area and consequently maximises sensor life.

The rear of the sensor has another flexible membrane, which is designed to accommodate internal volume changes that occur throughout the life of the sensor. Without this second membrane the sensing membrane would move to accommodate the internal volume changes, which would alter the sensors output.

The sensing membrane is made of Teflon whose thickness is very accurately controlled. The entire space between the two membranes is filled with a solution of potassium hydroxide.

The main sensor body is manufactured from high-density polyethylene.

Galvanic oxygen sensors require no external polarising voltage to work. They consume Oxygen and produce a small electrical current.



* Value determind by class of micro fuel cell
Removable Probe Assembly -
No Amplifier

The simplest Oxygen analyser employs no electronics, but is simply a sensor and a 100 micro Amps moving coil meter. The sensor used in the examples is a version of the Teledyne T-1 family

The sensor is made from several small parts each controlled to high standards. However no two sensors can be absolutely identical and therefore there will inevitably be differences in outputs. These are accommodated in the monitor by using a calibration control.

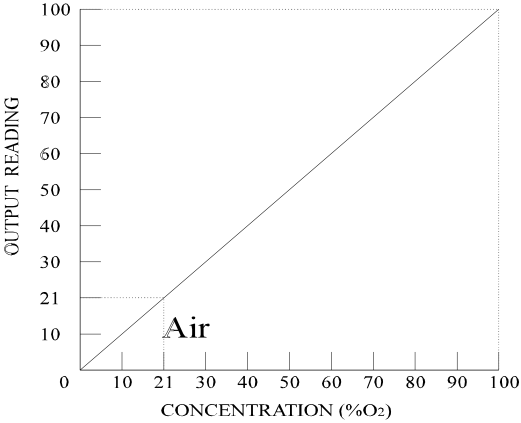
There is a family of Micro Fuel Cells with a common chemistry but each is designed to match an application. Anode size, type of membrane, body size, electrolyte and shape are chosen to enhance such requirements as speed of response, output requirements., or to meet size restraints.

The T-1 sensor, which can drive an analogue meter direct, has a large sensing area which is less prone to condensation effects but has a relatively slow response (30 seconds).

The R-17 has been designed to have a fast reponse and longer life (3 times the T-1) but has an output requiring electronic displays.

Sensor Linearity

The sensor output is linear over its range.



In the absence of Oxygen there is virtually no output from the micro fuel cell and so no zero or special calibration gases are required. It is specific to oxygen and for the purposes of this book is unaffected by inorganic and organic gases.

Strong inorganic oxidising gases e.g. . Chlorine, Fluorine, and Triflouride. can have an adverse effect on the sensor, *80% Helium has less than 1% effect on the measurement.*****

The Micro Fuel Cell has a very stable output and it is not uncommon for some sensors to run in a constant Oxygen concentration at STP for weeks and maintain a reading within +/- 1 %.

The advantage of using a T-1 type sensor with an analogue meter is the absence of batteries and associated electronics .

The T-1 type sensors are relatively slow compared to some sensors (30 seconds to register a 90% change) and have an expected life of 18 months in air or 4 months in 100% Oxygen. There are some advantages in the slower response in that the analogue reading does not fluctuate but is damped and steady.

The monitor shown in Fg. 19 is the simplest form of oxygen monitor available. The T-1 sensor generates about 1.0mA in 100% oxygen .

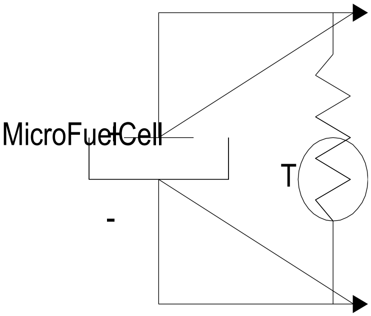
This can be used to drive a 100 microAmp moving coil meter with a 1 Kohm coil impedance. If the meter is replaced with a fixed 1 Kohmn resistor the output can be measured with a digital volt meter. The calibration control to compensate for small output variations between sensors is a linear 2Kohm resistor.

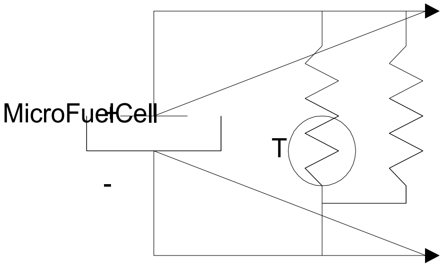
Sensor Linearity can be limited by the sensor output . As a temperature compensated voltage output increases beyond a certain point the sensors begin to become non linear E.g. the R-17 has a maximum output of 175 mV before it becomes non linear. As the output is 10.0 Mv in air and in 100% O_2 is 50mV it will become non linear at an Oxygen partial pressure of 3.5.Bar

The T-1 can be used up to 10 Bar

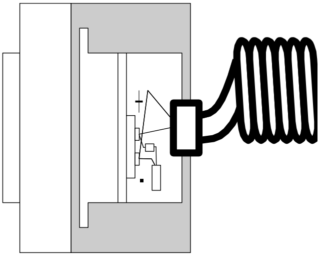
Temperature

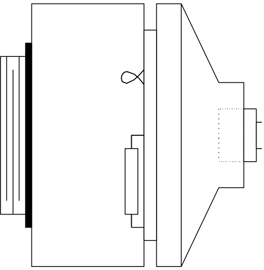
The Micro Fuel Cell sensor is temperature sensitive and increases its output by approximately 2.5% per degree Celsius. It therefore requires temperature compensation to maintain its accuracy. This is achieved by using a Thermistor resistor network across the sensor. With careful choice of components it is possible to match the tracking within 5% over the measuring range, which makes the error, at equilibrium insignificant.





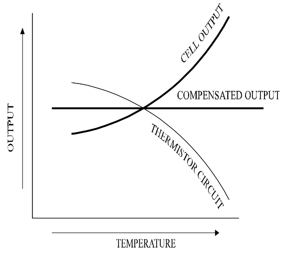
Temperature compensation can be built into the sensor, or into a sensor holder. Either of these of these methods produces the same effect.





T-1 sensors have external temperature compensation usually built into sensor holders

In sensors like the R-17 the temperature compensation circuit is located in the sensor immediately behind the socket.



The response of the temperature compensation circuit is designed to be exactly the opposite of the sensors response to temperature. With careful design the two effects can be cancelled out.

It is assumed that the sensor and the temperature compensation components are always at the same temperature. For most applications and the accuracy required, the assumption is correct. However if the gas is cold or hot, a temperature gradient will exist across the sensor.

The sensor has a thermal inertia, and time is required for it to heat up evenly .It is therefore possible for the gas being measured to be at a different temperature to the compensation circuit

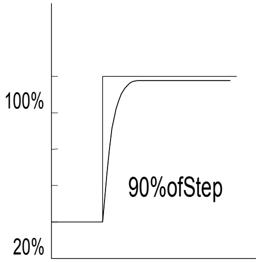
Adverse climatic conditions such as the Artic/Antartic can expose the sensor to its temperature limits for accuracy. In these conditions the human body being well-regulated temperature wise has been successfully used to stabilise the sensor temperature enabling accurate oxygen monitoring on a UK Everest climbing expedition.

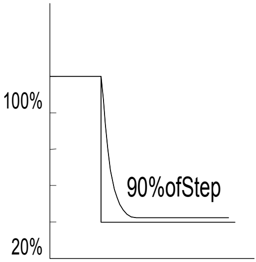
The temperature compensation components chosen depend upon sensor and application. Some sensors are used in normal climatic temperatures whilst others may be subjected to temperature extremes. The type of thermistor is chosen to suit the environment in which the sensor will be used.

For greatest accuracy the complete system should be allowed to rest at a stable temperature for 1 hour before calibration and measurement. As this is impractical in most applications of portable monitoring an awareness is required of temperature step changes.

Such step changes can be caused by moving from a warm room to freezing conditions outside hapter 12

Response time





The response time of sensors is defined as the time taken for the output of the sensor to reach

90% of the final reading on a step change.

Varying the thickness of the membrane during manufacture primarily controls the rate of Oxygen infusion into the sensor.

The thicker the membrane the slower the response.

Once the oxygen is through the membrane the rate of absorption depends on the partial pressure and the solubility of the electrolyte. The chemical reaction is also temperature dependant. The shape of the curve is exponential and after a rapid rise the rate of change progressively slows down. This is due to the equalisation of pressures between the gas and the electrolyte. Once the electrolyte is saturated a constant output is achieved. T

The last 10 % of reading can take several minutes particularly if the gas is stationary. By making the gas turbulent on the membrane as the molecules are absorbed into the sensor they are replaced by new gas keeping the partial pressure constant and the sensor reaches equilibrium faster. The curves above should be familiar to divers as it is identical to all gas exchanges i.e. Henry's law of differential pressures.

By making the gas turbulent the response time can be dramatically shortened.

The effect should be exactly the opposite if 100% oxygen is suddenly replaced by air 20.9%. In practice very often the gas is stationary. This means gas is trapped, particularly if a flow divertor is left attached. The trapped gas, being almost stationary gives erroneous readings. A moving gas is required to clear the sensor of the oxygen-enriched gas.

Accuracy

There are two main components affecting the accuracy of an instrument in a monitoring system assuming the sampling technique is correct.

Temperature:

The Thermistor network can achieve accuracy better than +/- 5% in tracking error, which in practical terms means that a temperature change of 5^{o} - 10^{o} C will produce a maximum error of +/- 1% of the reading. Measurements should be taken as soon as possible after a calibration and calibrations should be checked between measurements.

The method of display

When the micro fuel cell was originally introduced in the 1960 痴 electronic, circuits to amplify DC voltages were not so stable as today, so high output sensors and moving coil meters were the preferred method adopted.

This method was adequate and for most purposes +/- 2% was acceptable. The accuracy limitation was almost entirely due to the moving coil meter. The specific limitation of accuracy with analogue meters is encountered in calibration technique.

Setting a calibration of 20% instead of 20.9% is an error of 5%. However this results in a reading of 95% when the sensor is exposed to 100% oxygen. It is not uncommon with moving coil meters to only achieve maximum readings of 85% in 100% oxygen after a careless calibration at 21%.

To lessen the inaccuracies all analogue systems should always be calibrated first at 100% particularly if mixtures over 50% are to be measured. As this is the most accurate method of calibration it is a good rule of thumb for all oxygen analysers.

On top of user calibration inaccuracy most moving coil meters have accuracy of +/-2%. This depends upon the type of movement, scale length, and cost.

Digital readouts

Digital readouts can easily achieve a resolution +/- 0.1% and the errors can be contained well within the resolution of the final digit.

Calibration at 100% is still preferred to achieve the maximum accuracy over the complete range. Even with digital electronics and readouts a 1% reading error in air computes to a 5% reading error in 100%.

It should be noted that the accuracy of the digital meter can never exceed the resolution and at very low oxygen levels e.g. at 10 % the 0.1% resolution is equal to +/- 1% accuracy. This is important in trimix measurements.

The greatest measuring errors in the system will always be due to the operators.

These fall into three main categories:-

Accidental movement of the calibration control during period between calibration and measurement

Severe change in environmental circumstances.

Method of measuring the gas.

Calibration can only be valid at the time it is made and should be re-checked after the measurement.

The gas supplied for measurement should be at a constant temperature and at atmospheric pressure.

Sensor life

Sensor life is a series of trade off's. The basic formulae for the life of a sensor is governed by the amount of lead (physical size), the thickness of the membrane (speed of response) the amount of energy taken from the sensor (type of readout), and the amount of Oxygen.

The sensor life can be calculated as follows: using the equation

Life in months = $\underline{PB \times K \times 70\%}$ in 100% Oxygen

I =output current in Amps

Pb is the weight of Lead in grams

K= 3.59 x 10^{-4} (This is called the Proportionality constant and is a figure calculated by the designers that allows us to use the simple style of calculation}

70% = Anode efficiency.

Unfortunately it is impossible for the sensor to use up 100% of the lead. 70% is the worst case with most sensors providing 80-90% anode efficiency. NB Some companies work out the estimated life based on 100% giving much larger figures.

The Anodes are specifically designed to provide maximum consumption

As a rule sensors with an expected life in air of 48 months will have an expected life 1/5 of that in 100% oxygen i.e. 10 months.

A sensor has a life expectancy measured in Oxygen % Hours.

e.g. an R-17Med has a life expectancy of 700,000 $_{O}2$% Hrs

21% 36 months 50% 18 months 75% 9 months 100% 7 months

Sensor failure is relatively easy to establish by the manufacturer and all sensors returned with " premature failure" are examined. Due to manufacturing techniques exhaustion can only be achieved by exposure to Oxygen. All other premature failures will be observed as leaks or physical damage without normal deterioration of the anode or electrolyte.

The life of a sensor can be increased by the user if exposure to high concentrations is limited to the reading times only. i.e. remove the sensor from enriched Oxygen when it is not required.

Whilst the sensors are in a sealed gas barrier bag they are not consuming Oxygen and are not consuming lead.

Using a cell saver cap between uses will theoretically extend the life as it lowers the consumption of Oxygen and therefore slows down the rate it is using up the lead.

Other factors however play a part and one of the limiting factors is the electrolyte drying out.

The thin layer of electrolyte between the membrane and the anode plays an important part in keeping the anode wet which in turn assures a minimum internal resistance during the oxygen sensing reaction.

Membranes are manufactured in Teflon and are chosen carefully to match the sensor application. Thin membranes speed up the response but also allow water to diffuse more quickly out of the sensor. Thick membranes slow down the response and extend the working life of the sensor.

The ideal sensor has fast response yet long life.

By using modern electronic circuitry it has been possible to combine these requirements and with reduced output create a sensor with a 7 second response time and an expected life of 48 months in air without greatly increasing the physical size.

Such a sensor is the R-17, which has an output of 10.5mV in air nominally. The R-17 also has temperature compensation built into the sensor housing.

Although the R-17 and equivalent sensors have an expected life in air of 48 months from the day they are manufactured they are consuming oxygen and converting lead into lead oxide. Eventually they fail.

Failure of a sensor can be due to various factors.

The usable lead can be consumed.
The electrolyte can dry up.
The sensor can be physical damaged
The sensor can leak.

Theoretically the sensor could be starved of oxygen and many ingenious methods have been employed.

Many have used cell saver caps or sealed containers.

The theory being that the sensor uses up the oxygen in the volume of the cell saver cap or container and is left in Nitrogen, which does not oxidise the lead. This does have some effect although other factors begin to play a more active part as the sensor ages. Due to the long life of the sensors, leakage and electrolyte drying out is as common as lead depletion and care has to be taken concerning the environment surrounding the stored sensor.

Some sensors react to a depletion of Oxygen by going into a "sleep mode ". It can take 15 minutes for a sensor to wake up when re-introduced to air.

Other sensors show instability for some time on being released from a sealed environment. The T-1 sensors for instance can be left in air without the temperature compensation circuit and will not deteriorate as no current is flowing. However once introduced back into the measuring circuit it can take up to 8 hours for complete stability to be achieved. When manufactured these sensors are supplied in a gas barrier bag with a shorting clip across the output connectors. This is to reduce the time taken to achieve stability once the bag is opened.

R-17 & R-22 sensors have built in temperature compensation and therefore are never open circuit. This results in a quicker equilibrium when the bag is opened.

Heat in the form of closed cars on hot days will encourage dry-out. Sensors should never be left in sunlight.

Although the sensors are rugged and can work in any position they are comprised of small internal components. Severe mechanical shocks can physically cause damage internally.

When sensors near their exhaustion point they fail fairly quickly particularity in Oxygen enriched atmospheres so should not pose the threat of inaccurate readings. The effects of exhaustion or near exhaustion are obvious to the user. Rhodium cathode sensors display less of deterioration until very near exhaustion.

As the sensor reaches the end of its life the lead is used up and/or the electrolyte dries out. The internal resistance of the sensor increases, reducing the output.

This can be checked by calibration in 100% and checking that the sensor returns to at least 22% on re-exposure to air. Where 100% Oxygen is not available, sensors nearing exhaustion when calibrated in air may show drift mainly downwards but sometimes upwards either during calibration or when the sensor is returned to air after a reading.

Sometimes the electrolyte between the membrane and the cathode begins to dry out or has been squeezed by overpressure reducing the gap between the membrane and the cathode. In this instance the reduced volume of electrolyte and can display itself as a slowly increasing baseline.

Sensor outputs

The output of a micro fuel cell, although displayed as a percentage, is actually proportional to the partial pressure of the oxygen in the gas mixture. Applying Dalton's law as the pressure increases the partial pressure increases. As the pressure decreases the partial pressure decreases.

Pressures in excess of 1Bar can be generated naturally by high flow rates e.g. CPAP.

The sensor can be mounted in virtually any position, although older sensors may become position sensitive. Since the oxygen is diffused through a membrane the rate of flow across the sensor is not critical and can be 0.1-5.0litres /min. without a large change in reading or damage to the sensor. This still depends on no backpressure being produced on the sensor face. The sensor measuring position should always include an escape route for the gas to the atmosphere. Particularly at high flow rates any resistance

The micro fuel cell was designed to be insensitive to shock, vibration and position. If the sensor is turned upside down quickly the baseline may show some movement due to the pressures generated inside the sensor case but should quickly return to its start point. The sensor can be accidentally dropped and usually has no ill effects unless the membrane is damaged. However the sensor is a mechanical device and can be damaged

Humidity and water

Humidity does not directly affect the accuracy of the sensor however

Excessive moisture or condensation on the sensor surface will block diffusion of oxygen to the sensor and render it inoperative. Henry's law is very important here as the gas is in one liquid on the membrane and needs to transfer into another liquid the electrolyte in the sensor.

In high humidity atmospheres hold the sensor facing down during calibration. The surface tension of the liquid will form droplets .Any droplets formed will have a chance to fall off the sensor membrane allowing gas a direct path. The sensing surface can also be dried with a soft absorbent tissue

Environments of 100% Humidity create a situation where the water vapour takes up a measurable volume of the gas and therefore reduces the partial pressure of the oxygen present in the air and reduces the reading

This effect can be calculated as follows.

Assuming STP Temperature = 25oC pressure = 760mm and the gas is fully saturated 100% relative humidity

The Water vapour pressure from the standard tables is 23.756 mmHg

Vapour pressure tables exist which provide reference of water vapour pressure against temperature

$$\%H_2O = 23.756 \times 100 / 760 = 3.13\%$$

This is how much water vapour exists in the gas

Instead of reading 20.9% in saturated Air with 20.9% Oxygen the actual reading would be

$$20.9 - (20.9 \times 3,.13)/100 = 20.25\ \%$$

Error =0.65%

In order to use the tables correctly the atmospheric pressure and temperature should be known and the Relative Humidity should be 100%.

The possible calibration error of 0.65 should be borne in mind if the accuracy of gas mix is important.

As the gas from the cylinder to be measured is dry if the calibration was carried out using 100% dry Oxygen or 20.9% dry Air from cylinders the problem ceases to exist.

Pressure

At sea level in air the partial pressure of Oxygen is approximately 0.21 and the percentage of Oxygen will therefore read approximately 21%. If the sensor were subjected to 2 BAR pressure in air it would read 42% (Partial pressure 0.42 Bar).

It is important that pressures on both membranes should be equal at all times..

Temporarily exposing the front membrane to high pressures will distort the front membrane and if the rear membrane is sealed pressure inside the sensor will increase and permanent damage can result. The rear membrane should always be at ambient pressure and should never be sealed.

During installation and use take care not to touch or puncture the membrane. Oils from the skin can block the diffusion path.

Sensor electrolyte is caustic. Never let the electrolyte come into contact with skin eyes or mouth. If it does, flush the affected area with fresh water.

Never attempt to open or repair a sensor.

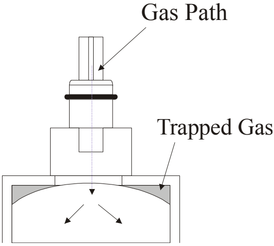
Check the sensor regularly for leaks. Leaking or exhausted sensors should be disposed of in accordance with local regulations, which is usually similar to the disposal of batteries.

For any problems with leakage or disposal consult the material safety data sheets

Never Store sensors for long periods before use.
Never Subject sensors to High Temperatures i.e. (Car rear shelf)
Never freeze sensors (left in cars overnight)
Never Subject sensors to physical shocks.
Never Subject sensors to vacuum
Never Submerge sensors in liquids

Never Attempt to open a sensor.

Flow Divertor



The flow divertor is designed to be used only in conjunction with the tee piece and only in flowing gases. Flowing gas is diverted onto the sensor face causing turbulence and decreases the time it takes the sensor to respond.

Failure to remove the divertor in static gas can cause the response time to be lengthened substantially and gas can become trapped in the area between the flow divertor bottom and the membrane.

It is essential that moving gas be present when the divertor is being used.

Flow rates between 0.1ltr/min and 5 ltr/min should be used for both accurate Calibration and measurement. This allows adequate clearance of the gas without the build up of unwanted pressure.

However the most accurate measurements will be achieved if the flow is reduced to zero with the measuring circuit open to atmosphere during the actual measurement. This gives the benefit of turbulence and good gas exchange into the sensor yet allows the measurement to be made at 1 Bar

The most accurate method of measuring 100% oxygen is to use the Flow Divertor, Tee Piece and a length of tubing

Material Safety Data Sheet

This information is specific to Teledyne Micro fuel cells and although other manufacturers products world-wide may exhibit similar properties no claim is made that this information can be used to describe those products.

Product Identification

Product Name: Micro-Fuel Cells R-17

Manufacturer:

Teledyne
Address: 16830 Chestnut Street,
City of Industry,
CA 91749
Date Prepared or Last Revised: 08/08/91

Emergency Phone Number: 0101 818 961 9221

Physical and Chemical Data

Chemical and Common Names : Potassium Hydroxide (KOH), 15% (w/v)
Granular Lead (Pb), pure

CAS Number : KOH 1310-58-3

Pb 7439-92-1

	KOH	Pb
Melting Point/Range:	10° to 0° C	328° C
Boiling Point/Range:	100° to 115o C	1744° C
Specific Gravity:	1.09 @ 20° C	11.34
pH:	14	N/A
Solubility in Water:	Completely soluble	Insoluble
Percent Volatile by Volume:	None	N/A

Appearance and Odour Colourless, Grey metal, Odourless
Solution

Physical Hazards
Potential for fire and explosion
The electrolyte in the Micro-Fuel Cells is not flammable.
There are no fire or explosion hazards associated with Teledyne R17 sensors.
Potential for reactivity: The sensors are stable under normal conditions of use. Avoid contact between the sensor electrolyte and strong acids.
Health Hazard Data

Primary route of entry : Ingestion, eye/skin contact

Exposure limits:OSHA PEL : .05 mg/cu.m (Pb)

ACGIH TLV : 2 mg/cu.m. (KOH)

Effects of over-exposure

Ingestion : The electrolyte could be harmful or fatal if swallowed.

Eye : The electrolyte is corrosive; eye contact could result in permanent loss of vision.

Dermal : The electrolyte is corrosive; skin contact could result in a chemical burn

Inhalation : Liquid inhalation is unlikely.

Signs/symptoms of exposure:

Contact with skin or eyes will cause a burning sensation and/or feel soapy or slippery to touch.

Medical conditions

aggravated by exposure : None

Carcinogenity: NTP Annual Report on Carcinogens

Not Listed LARC Monographs: Not

Listed, OSHA:

Other health hazards : Lead is listed as a chemical known to the

State of California to cause birth defects

or other reproductive harm.

Emergency and First Aid Procedures

Eye Contact : Flush eyes with water for at least 15 minutes and get immediate medical attention.

Skin Contact: Wash affected area with plenty of water and remove contaminated clothing. If burning persists, seek medical attention.

Ingestion: Give plenty of cold water. Do not induce vomiting. Seek medical attention.

Inhalation: Liquid inhalation is unlikely.

Handling Information

The oxygen sensors are sealed, and under normal circumstances, the contents of the sensors do not present a health hazard.

The following information is given as a guide in the event that a cell leaks.

Protective clothing: Rubber gloves, chemical splash goggles

Clean-up procedures: Wipe down the area several times with a wet paper towel. Use a fresh towel each time

Protective measures

During sensor replacement: Before opening the bag containing the sensor, check the sensor for leakage. If the sensor leaks, do not open the bag. If there is liquid around the sensor e.g. whilst in the instrument case, put on gloves and eye protection before removing the sensor.

Disposal

Should be in accordance with all applicable state, local, national and federal regulations.

NOTE: The above information is derived from the MSDS provided. The information is believed to be correct but does not purport to be all-inclusive and shall be used only as a guide. Teledyne shall not be held liable for any damage resulting from handling or from contact with the above product.

Storage of sensors.

The useful life of the cell depends upon the concentration of oxygen and temperature. If it is left inside the sealed gas barrier bag at ambient temperature its life expectancy should only deteriorate by 1/20 of its in air life per year.

It is not recommended that sensors be stored longer than one year. Microscopic leaks similar to flashlight batteries may develop which may damage the electronic connections.

Warranty

Micro Fuel Cell has to be viewed like a battery. Once manufactured its use depends almost entirely on the way it is used. Once the bag is broken the manufacturer has no control. The bags should be examined before opening for signs of leakage or damage. The manufacturer gives a one year limited warranty on the sensors from the date despatched. This is limited to faulty workmanship or materials but not exhaustion.

Sensors stored for many months may not be covered by warranty when the bag is opened. Always purchase fresh sensors. All sensors have a serial number, which can be traced to date of manufacture and quality control examinations. Never remove the label or deface the serial number.